Changes in the structure of the accretion disc of HS1804+67 through the outburst cycle [1]

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Abstract

We report on the analysis of high-speed photometry of the dwarf-nova HS1804+67 through its outburst cycle with eclipse mapping techniques. Eclipse maps show evidences of the formation of a spiral structure in the disc at the early stages of the outburst and reveal how the disc expands during the rise until its fills most of the primary Roche lobe at maximum light. During the decline phase, the disc becomes progressively fainter as the cooling front moves inwards from the outer regions, until only a small bright region around the white dwarf is left at minimum light. The variable part of the uneclipsed light is possibly due to emission in a wind emanating from the inner parts of the disc. The emission from this region is sensitive to the mass accretion rate.

1. Introduction

Dwarf novae yield an uneven opportunity to study the time evolution of non-stationary accretion discs, in particular in the transition between the high and low viscosity (and accretion rate) states which are believed to occur during the outbursts of these objects. HS1804+67 is a long period ($\simeq 5.5$ hs) eclipsing dwarf nova with outbursts of moderate amplitude ($\simeq 1 - 2$ mag) and recurrence intervals of ~ 1 month [Billington et al, 1995, Fiedler et al, 1997].

In this paper we report on the results of the analysis with eclipse mapping techniques [Horne, 1985] of a set of lightcurves of HS1804+67, which allows to follow the evolution of the structure of its accretion disc through the outburst cycle. The eclipse maps capture "snapshots" of the disc brightness distribution on the rise to maximum, during maximum light, through the decline phase, and at the end of the eruption – when the system goes through a phase of minimum light before recovering its quiescent brightness level.

2. Observations and analysis

Time series of CCD differential photometry of HS1804+67 in the R band were obtained with the JGT 1-m telescope at the University of St. Andrews during 1995-96 covering 4 consecutive eruptions of the star. The data were grouped and average lightcurves were obtained for 11 different phases through the outburst cycle. The average lightcurves were analyzed with eclipse mapping techniques to produce a map of the disc brightness distribution and an additional uneclipsed component in each case. The data lightcurves and corresponding eclipse mapping models are shown in Fig. 1. Maps of the brightness distribution for 9

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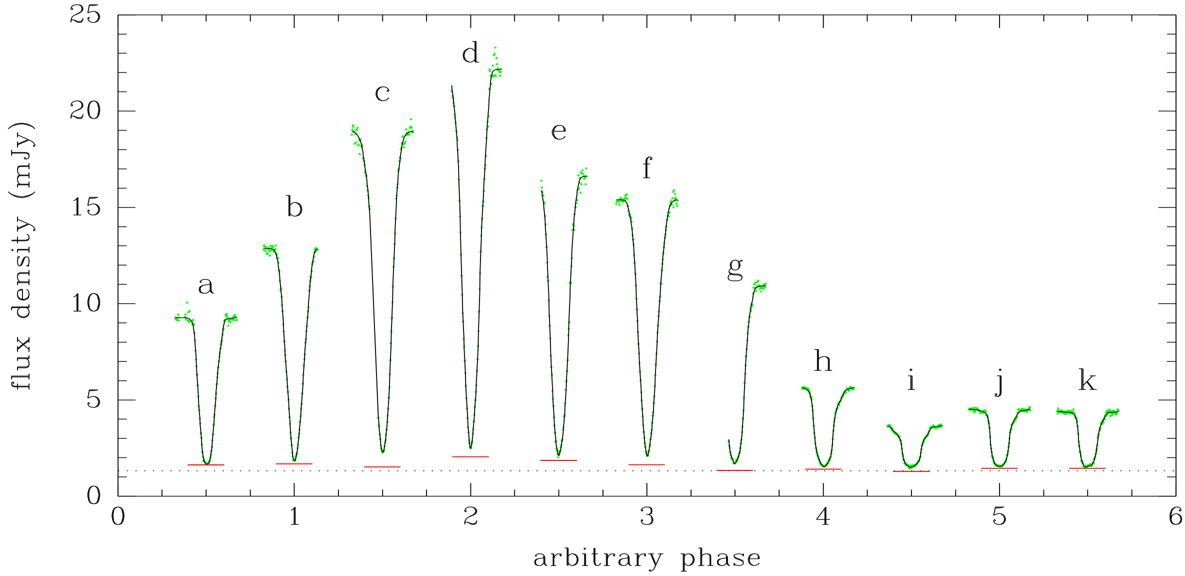

Fig. 1. Average lightcurves of HS1804+67 seen in a sequence through the outburst cycle. The separation of the lightcurves in the x axis is arbitrary. The solid lines are the eclipse mapping model lightcurves. The uneclipsed component in each case is indicated by a horizontal tick; a dotted horizontal line mark the value of the uneclipsed component at minimum light.

of the lightcurves are shown in Fig. 2 in a logarithmic grayscale. Fig. 3 shows the evolution of the radial intensity distribution in the disc of HS1804+67 through the outburst cycle.

3. Discussion

The results reveal the formation of a spiral structure at the early stages of the outburst (fig. 2a) and shows how the disc expands until it fills almost all of the primary Roche lobe at maximum light (figs. 2c and 3), becoming progressively fainter through the decline while the bright spot starts to become more and more perceptible at the outer edge of the disc (figs. 2d-h and 3). At the phase of minimum the disc mostly disappears, leaving only a small bright region around the white dwarf, possibly a boundary layer (fig. 2i). In quiescence the disc is asymmetric, with the region along the gas stream trajectory being noticeably brighter than the neighbouring regions (fig. 2j). This is is agreement with the results obtained from Doppler tomography of Hα emission [Billington et al, 1995].

The comparison of the maps during the rise to maximum indicates that the eruption starts in the outer disc and that a heating front wave (which triggers the high viscosity and mass accretion state) moves inwards and reaches the central parts of the disc at outburst maximum. A cooling front wave characterizes the decline of the eruption and also propagates from the outer parts to disc centre (fig. 3) reaching the central parts of the disc by the end of the outburst (fig. 2h). The comparison of the maps at minimum light and at quiescence suggests that mass accretion over the white dwarf is substantially reduced in the former phase and that probably most of the matter transferred from the secondary star at these stages accumulates in the outer disc, restarting the eruption cycle.

The evolution of the uneclipsed flux through the outburst can be seen in Fig. 1. A dotted line indicate the value of the uneclipsed component at minimum light and is interpreted as being due to the (fixed)

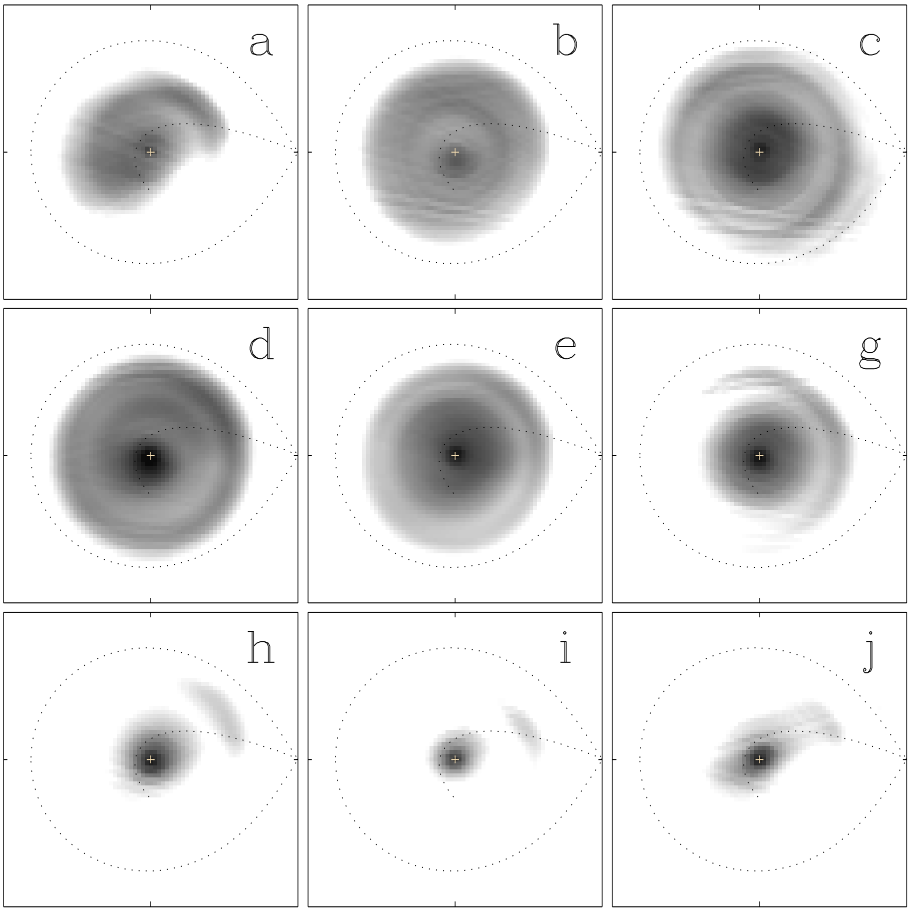

Fig. 2. Sequence of eclipse maps of HS1804+67 through the outburst cycle. Labels are the same as in Fig. 1. Brighter regions are dark ($\log I = -2.8$) and fainter regions are white ($\log I = -5.6$). A cross mark the center of the disc; dashed lines shows the projection of the Roche lobe on the orbital plane and the gas stream trajectory; the secondary is to the right of each panel and the stars rotate counter-clockwise.

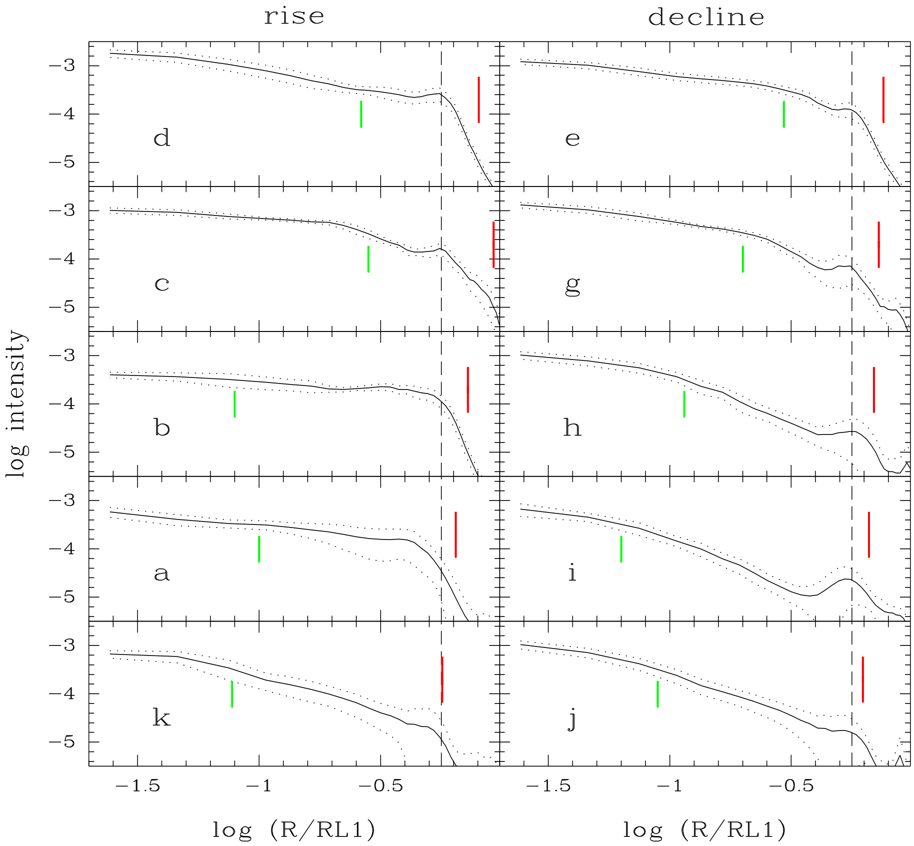

Fig. 3. The evolution of the radial intensity distribution through the outburst. Labels are the same as in Figs. 1-2. R_{L1} is the distance from disc centre to the inner Lagrangian point. Dashed lines indicate the radial position of the bright spot in quiescence. Vertical long ticks mark the position of the outer disc edge and vertical short ticks indicate the radial position at which the disc intensity drops below $\log I = -3.5$.

contribution of the secondary star to the flux in the R band. The variable part of the uneclipsed component is probably due to emission in a vertically extended disc chromosphere + wind. Fig. 1 shows that the emission from this latter region follows the changes in brightness of the inner parts of the disc during the outburst. At minimum light, when mass accretion at the inner disc is substantially reduced, the emission in the disc chromosphere + wind practically disappears. These results support the suggestion that the ejection of material in the wind originates from the inner parts of the disc and that the emission of the resulting chromosphere + wind is sensitive to the disc mass accretion rate, in accordance to inferences drawn by a similar study of the novalike UX UMa [Baptista et al, 1998].

References

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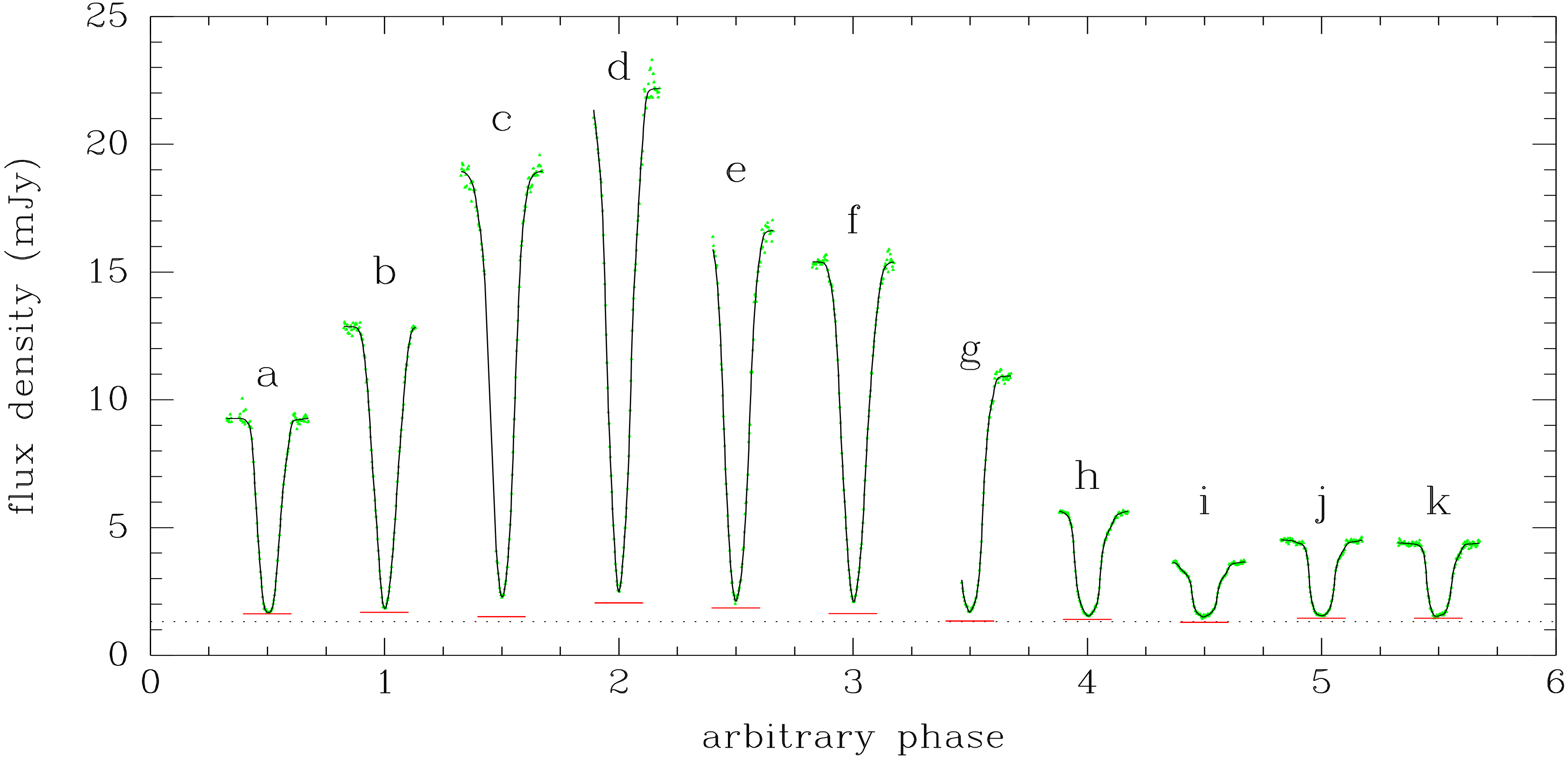
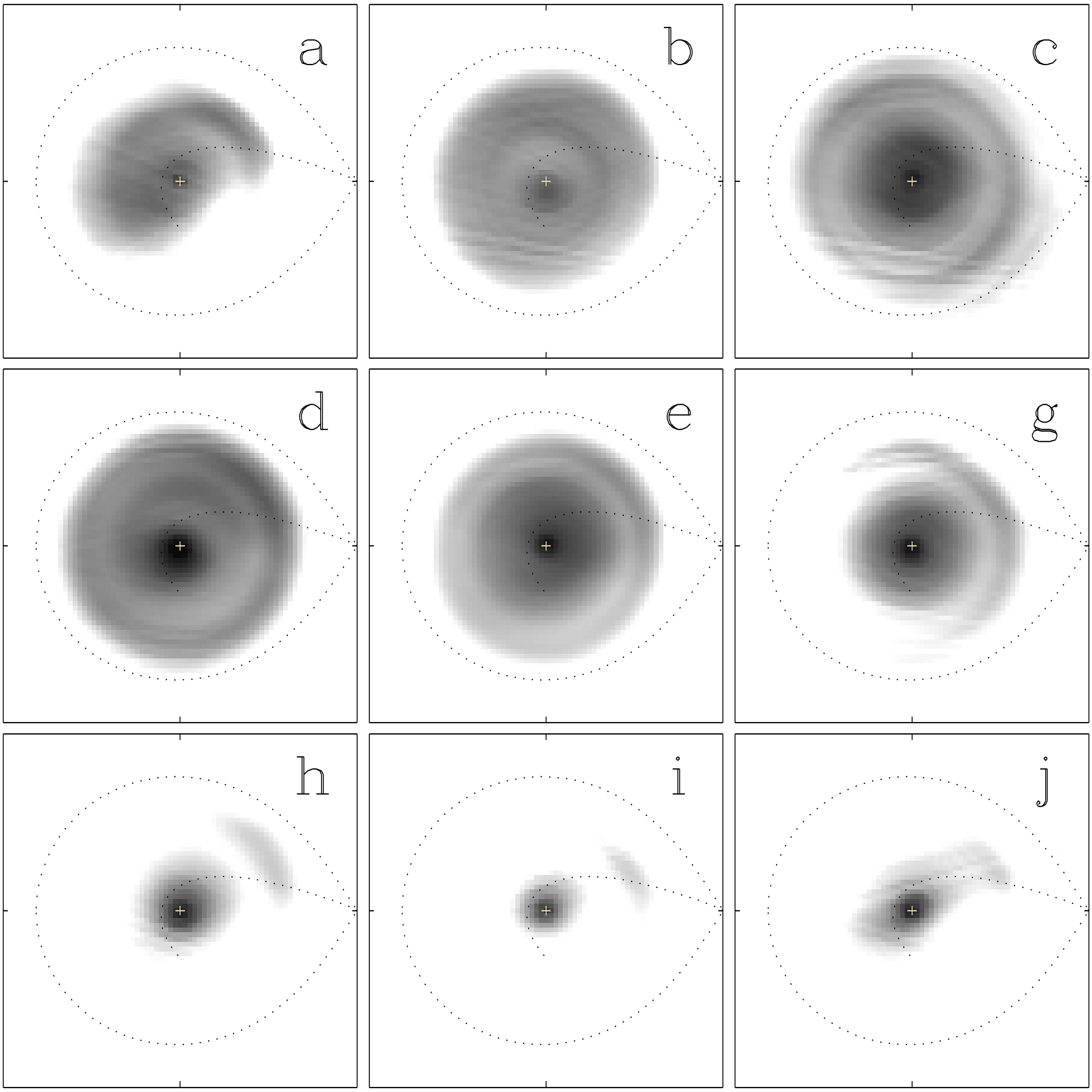

flux density (mJy)
arbitrary phase
a
b
c
d
e
f
g
h
i
j
k
0
5
10
15
20
25
0
1
2
3
4
5
6


a
b
c
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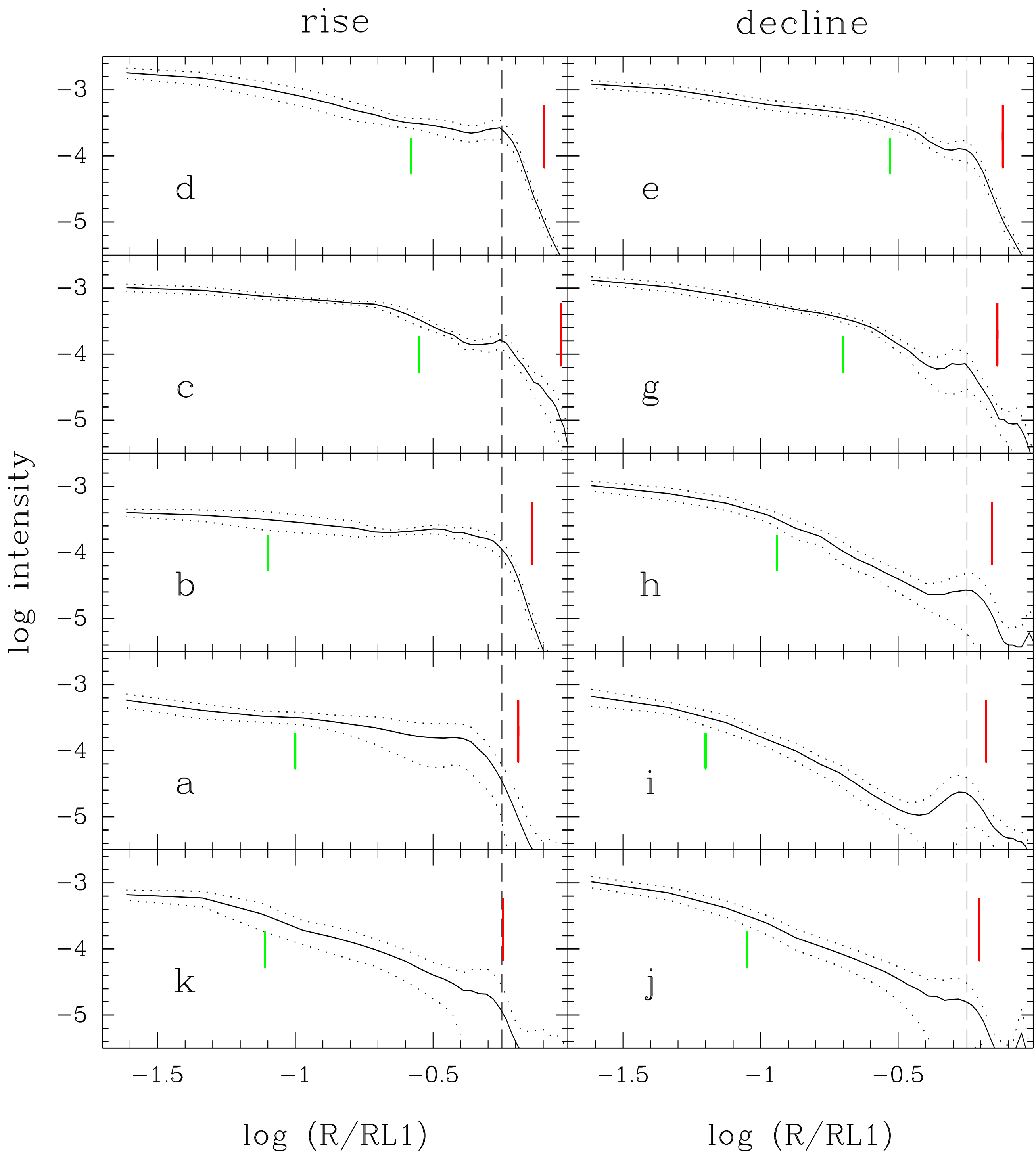

rise
decline
log intensity
log (R/RL1)
log (R/RL1)
−3
−4
−5
−1.5
−1
−0.5
d
e
c
g
b
h
a
i
k
j